ARTÍCULO ORIGINAL

Spray drying of calcium and magnesium citrate from dolomite

Secado por aspersión de citrato de calcio y magnesio a partir de dolomita

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ABSTRACT

Introduction: calcium is an essential nutrient required in substantial amounts, but many diets are deficient in calcium making supplementation necessary or desirable. On the other hand, spray drying is an important technology used in the pharmaceutical industry. In this process the end-product must comply with precise quality standards.
Objective: To evaluate the spray drying of calcium and magnesium citrate and to make comparison with the traditional method of drying.
Methods: calcium and magnesium citrate salt was obtained at bench scale from dolomite and suspended in water in a proportion 1:10 (w/v) and spray-dried. The final batches were evaluated by chemical and technological analysis methods
Results: the results showed that calcium, magnesium, citric acid and total ash content have similar concentrations regardless of the used drying method. Residual moisture content of the dried product by spray drying method was higher than that of the dried sample by traditional method. Nevertheless, all the results were below the maximum allowable limit. The physical properties of the samples for each drying method were similar except for density because the spray-dried samples showed values lower than those of traditionally dried samples.
Conclusions: the results indicate that the tested spray drying conditions are suitable for drying of calcium and magnesium citrate from dolomite

Keywords: calcium and magnesium citrate, residual moisture content, Dolomite, density, spray dried.

RESUMEN

Introducción: el calcio es un nutriente esencial que se requiere en cantidades sustanciales, pero muchas dietas son deficientes de calcio, lo que hace necesario suplementar el mismo. Por otro lado, el secado por aspersión es una tecnología importante usada en la industria farmacéutica. Con este proceso de secado se obtiene un producto final que obedece a los estándares de calidad necesarios.
Objetivo: este estudio se realizó para evaluar el secado por aspersión del citrato de calcio y magnesio y su comparación con el método tradicional de secado.
Métodos: se obtuvieron lotes de citrato de calcio y magnesio a escala de banco a partir de dolomita y se suspendieron en agua en una proporción 1:10 (masa/volumen). Posteriormente fueron secados mediante secado por aspersión. Se evaluaron los lotes obtenidos mediante métodos de análisis químicos y tecnológicos.
Resultados: los resultados mostraron que el contenido de calcio, magnesio, ácido cítrico y cenizas totales eran similares independiente del método de secado empleado. El contenido de humedad residual en las muestras secadas por aspersión fue superior al de las muestras secadas por el método tradicional. No obstante, los resultados obtenidos en ambos casos estaban por debajo del límite máximo permisible. Las propiedades físicas de las muestras para cada método de secado estudiado fueron similares, excepto para la densidad, dónde se observó que las muestras secadas por aspersión tienen valores de densidad menores que las muestras secadas por el método tradicional.
Conclusiones: los resultados demuestran que las condiciones de secado por aspersión estudiadas son adecuadas para el secado del citrato de calcio y magnesio obtenido a partir de dolomita.

Palabras clave: citrato de calcio y magnesio, contenido de humedad, Dolomita, densidad, secado por aspersión.

INTRODUCTION

Drying may be defined as the vaporization and removal of water or other liquid from a solution, suspension, or other solid-liquid mixture to form a dry solid. Drying is normally associated with the removal of relatively small quantities of liquid to give a dry product. During the trial of drying of a material, static dryers or continuous dryers can be used. Spray dried is a continuous dryer's type used to dry diverse materials in the industry. As the name implies, the solution or suspension to be dried is sprayed into a hot airstream and circulated through a chamber. The dried product may be carried out to a cyclone or bag separator or may fall to the bottom of the drying chamber and be expelled through a valve. The chambers are normally cylindrical with a conical bottom, although proportions vary widely.[1]

Spray drying is an important technology used in the pharmaceutical industry. In this process the end-product must comply with precise quality standards regarding particle size distribution, residual moisture content, bulk density and morphology.[2,3]

Calcium is an essential nutrient required in substantial amounts, but many diets are deficient in calcium making supplementation necessary or desirable. The absorption of calcium from dietary supplements has been studied by many methods. Some studies have shown the more soluble calcium citrate to be somewhat better absorbed than the relatively insoluble calcium carbonate.[4-6]

A process to obtain calcium and magnesium citrate from dolomite has been developed. This process consists on making react dolomite with citric acid, with later precipitation of the calcium and magnesium citrate.[7] Hot air ovens during eight hours to dry the end-product were used.[8] This study aimed to evaluate the spray dried of the calcium and magnesium citrate and their comparison with the traditional method of drying.

METHODS

MATERIALS

Dolomite (*GEOMINERA, Cuba*) and citric acid (*Proquibasa, Spain*) were used. Both compounds obtained commercially were of the highest purity in accordance with the monographs of quality of the makers.

PREPARATION OF CALCIUM AND MAGNESIUM CITRATE SALT

Calcium and magnesium citrate salt was obtained at bench scale from dolomite in accordance with a modification to the procedure described in earlier paper.[7] The modification consisted in the filtered sample is suspended in water in a proportion 1:10 (w/v) and dried by spray dried.

The parameters of dryings were carried out according to Vidal et al.[9] The suspension was spray dried in a Büchi B 191 model spray dryer (Switzerland). Inlet air temperature (180 °C) and outlet air temperature (100 °C) were carried out. The product was fed into the spray dryer at room temperature 600 L/h: the rate was varied to regulate exit air temperature at the desired value. After cooling to room temperature, the powder was placed in plastic bags and stored until analysis. The results were compared with the traditional method of drying, consistent in the drying of the product in hot air ovens (static drying) during 8 hours at 100 ºC.[8]

EVALUATION OF CALCIUM AND MAGNESIUM CITRATE SALTS

*Chemical evaluation: c*alcium and magnesium determination (complexometric method) and citric acid determination (volumetric method) were used according to Rodriguez y col.[10] Moisture content and total ash according to USP were determined.[11]

BULK AND TAPPED DENSITY (HAUSNER´S RATIO AND CARR´S COMPRESSIONAL INDEX)

The density parameters (bulk and tap densities) were determined using an appropriate amount of the sample was poured in a 100 mL tared graduated cylinder. The volume was then read directly from the cylinder and used to calculate the bulk density according to the mass/volume ratio. For tap density the cylinder was tapped 1 000 times using a tap density analyzer (*Erweka SVM1, Germany*). The flow rate was measured by a glass funnel with a round orifice of 120 mm, its outlet is separated 100 mm respect to a horizontal surface, and with a wall angle of 45 degrees.[12]

POWDER PARTICLE SIZE ANALYSIS

The particle size distribution was measured using a laser scattering particle size analyzer (model LS 230, *Beckman Coulter, USA*). For measurement, the sample was diluted to less than 0,02 % w/w to prevent multiples scattering effects. The size distribution of sample powders was determined by dispersing them in absolute ethanol and analyzing them with the same laser scattering spectrophotometer. Determinations were done in triplicate. The powder was characterized as the average particle size (µm).

STATISTICAL ANALYSIS

Obtained results were expressed as mean ± standard deviation (SD) and assessed by analysis of variance (ANOVA) followed by *Duncan's* test. Results were considered significant when $p< 0.05$.

RESULTS

The table 1 show the results of chemical evaluation of the studied batch. Calcium, magnesium, citric acid and total ash content have similar concentrations independent of the drying method used. These results coincide with results reported in previous works.[8,10,13]

Residual moisture content presented on dried product by spray dried was bigger than 7,5 %. While the residual moisture content presented on dried product by traditional method was smaller than 5,0 %, considered appropriate by analytical method of products. The statistical comparison showed significant differences ($p=$ 0,020) between the drying method used

Table 2 show the physical properties of the samples for each method of studied drying. Concerning the sample density, in both cases descending values of tapped density>bulk density were observed. The high values of Hausner's ratio and Carr's index are indicative of an extremely poor flow according to USP [11] causing their inability to flow. A high porosity percentage was observed motivated maybe by the packaging type of the solid mass. The particle size was considered appropriate.

Table 1. Results of chemical evaluation of the studied batch

Spray dried process (SD)			
Parameter evaluated	Batch SD-1	Batch SD-2	Batch SD-3
Calcium (%)	12,50 / 0,17	12,70 / 0,15	12,60 / 0,12
Magnesium (%)	4,20 / 0,06	4,20 / 0,03	4,26 / 0,16
Citric acid (%)	0,70 / 0,06	1,22 / 0,09	0,47 / 0,38
Total ash (%)	29,1 / 0,13	29,0 / 0,19	29,2 / 0,15
Moisture content (%)	7,90 / 0,30	7,80 / 0,27	7,86 / 0,55
Traditional dried process (TD)			
Parameter evaluated	Batch TD-1	Batch TD-2	Batch TD-3
Calcium (%)	12,92 / 0,06	12,97 / 0,09	12,49 / 0,20
Magnesium (%)	4,41 / 0,11	4,30 / 0,05	4,22 / 0,06
Citric acid (%)	0,32 / 0,01	0,10 / 0,03	0,50 / 0,05
Total ash (%)	31,0 / 0,15	29,4 / 0,11	29,4 / 0,14
Moisture content (%)	4,41 / 0,25	4,56 / 0,21	4,53 / 0,22

The results correspond to mean / DS the average of three determinations (n=3)

Table 2. Physical properties of calcium and magnesium citrate samples

Spray dried process (SD)			
Parameter evaluated	Batch SD-1	Batch SD-2	Batch SD-3
Bulk density (g/cm^3)	0,135 / 0,15	0,153 / 0,17	0,206 / 0,13
Tapped density (g/cm^3)	0,249 / 0,16	0,313 / 0,22	0,416 / 0,28
Porosity (%)	45,8 / 0.4	51,2 / 0,4	51,2 / 0,1
Flow rate (g . cm^{-2} . s^{-1})	*	*	*
Haussner's ratio	1,80	2,00	2,00
Carr's Index (%)	45,9	51,1	51,2
Particle size (□m)	13,0 / 1,5	12,8 / 0,8	13,6 / 1,3
Traditional dried process (TD)			
Parameter evaluated	Batch TD-1	Batch TD-2	Batch TD-3
Bulk density (g/cm^3)	0,270 / 0,15	0,239 / 0,17	0,324 / 0,13
Tapped density (g/cm^3)	0,575 / 0,19	0,477 / 0,12	0,534 / 0,18
Porosity (%)	51,3 / 0.8	50,0 / 0,7	49,5 / 0,8
Flow rate (g . cm^{-2} . s^{-1})	*	*	*
Haussner's ratio	2,00	1,99	1,80
Carr's Index (%)	51,3	50,0	46,6
Particle size (□m)	70,9 / 1,9	71,2 / 1,5	70,5 / 1,2

The results correspond to mean / DS the average of three determinations (n = 3). * Determination not possible due to blocking of the funnel

DISCUSSION

A fine powder was obtained in the samples dried by spray dry. In both cases, the powder was white colour, soluble in hydrochloric acid solution and insoluble in water. Calcium and magnesium are the main components in the sample.

The quality of the powder is based on a variety of properties that depend on specific application. In general, the final moisture content, solubility, rheological properties, and density are of primary importance. These physical properties include moisture content, apparent density, true density and respective particle porosity, particle size, and its distribution. These properties are influenced by the nature of the material (solid content, viscosity, and temperature), type of spray dryer, operational speed atomization or pressure nozzle, and air inlet and outlet temperatures.[14-16]

A critical process control parameter during the spray dryer is the humidity of the exhaust air. Thermodynamic modeling was used to estimate the humidity of the exhaust air for a particular set of processing conditions. However, this methodology was not able to predict most particle/powder related attributes such as particle size and moisture level. On the other hand, the process of atomization and particle formation events occur in sequence, where the droplets formed come into contact with the hot gas leading to evaporation of the solvent and solute precipitation.[2] The understand of these processes can help to improving powders attributes.

In the pharmaceutical applications pressure nozzles are preferred to two-fluid nozzles, however, when feeds have very high viscosities or large suspended materials may block the nozzle orifice. To avoid this situation, the quantity of water is generally increased being bigger the residual moisture content in the final product.

In this case, the product contained high concentration of particles in suspension what blocked the nozzle orifice, being necessary to dilute the solution until 10 % of particle in suspension. As consequence of this process a high content of water is necessary to evaporate with an increment of the humidity of the exhaust air. This situation causes a superior content of residual moisture in the samples dried by spray dried. Nevertheless, the obtained results were below the permissible maximum limit (10 %).[17] These results are also inferior to Calcium citrate available commercially which contains about 13 % water.[9,11]

The density is an essential parameter in the characterization of the powders. It can be observed that the samples dried by spray dried have bulk and tap density values smaller than the bulk and tap density values of the samples dried by the traditional method. This is because the porous structures are favored by high drying rate promoted by the use of high temperatures due to the expansion of evaporation of water vapour leaving the empty spaces occupied by the air. The particles occupy space with little weight.[16,18]

The porosity values were in the range of 45 % to 52 % for both samples and were not affected by the conditions of drying under study. The high porosity percentage observed was motivated maybe by the packaging type open of the solid mass. It is cause of the packaging type open of the solid mass, indicating the tendency of the material to form agglomerates, affecting the rheology properties of the samples. These results coincide with previous studies.[13]

On the other hand, the Hausner's ratio and Carr's index were not affected by the conditions of drying. In both cases, high values of Hausner's ratio and Carr's index was observed. These results confirm an extremely poor flow according to USP causing their inability to flow.[11]

The particle size was smaller in the dried samples by spray dried. This is because an increase of the atomization speed due to higher atomizer wheels speeds, decrease of droplet and therefore particle size.[19]

A white powder with moisture contents about 6% and a bulk density between 0.3 and 0.7 g/cm^3 was obtained by Vidal et al when drying by spray dried calcium citrate obtaining by neutralization of citric acid with calcium hydroxide.[9] These results are similar to the obtained by these authors. This indicates that the drying conditions are important in the obtaining of calcium and magnesium citrate salts with a moisture content and particle size appropriate.

In conclusion, the results indicate that the spray drying conditions studied to dry calcium and magnesium citrate were satisfactory.

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